

## **Tools to Compare Diving-Animal Kinematics with Acoustic Behavior and Exposure**

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### **LONG-TERM GOALS**

Intense international concern has arisen over the potential effects of anthropogenic sound on protected marine wildlife. To study this issue presents a challenge, however, because marine animals in captivity form a limited sample set that cannot always be extrapolated to wild populations, while those in the wild spend the majority of their time submerged and out of sight of researchers. Thus instrumentation to monitor the behavior and sound exposure of wild, free-ranging marine animals is essential.

Broadband acoustic recording tags offer a promising avenue for studying the relationship between behavior and sound exposure for free-ranging animals. Since 1995, when the first combined broadband-acoustic and behavior recorders were deployed with northern elephant seals (Burgess et al., 1998) such tags – predominantly the DTAG (Johnson and Tyack, 2003), the Bioacoustic Probe (Burgess, 2000), and the Acousonde (Figure 1; Burgess, 2009) – have seen extensive use in the study of whales and seals (e.g., Insley et al., 2007; Miller et al., 2004; Oleson et al., 2007). These studies have generated dramatic quantities of acoustic, depth, and orientation data, and as such tags become increasingly available the amount of data will continue to grow. This rapid expansion of data will not, however, support the commensurate expansion of study and understanding unless the wider research community is equipped to process and interpret those data effectively.

This program focuses on the collaborative improvement of two tools for acquiring and interpreting broadband acoustic and behavioral data: the “Acousonde™” broadband acoustic-and-behavior recorder (Figure 1) and the “TrackPlot” kinematic-analysis software. Under this effort, Greeneridge Sciences (the Acousonde) and the University of New Hampshire (TrackPlot) are improving their respective tools in concert to maximize the data acquisition and interpretation capabilities of the wider bioacoustic research community. The three fundamental principles guiding development of both tools towards this transition are ease of use, flexible design, and broad availability.

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***Figure 1. Photograph of the Acousonde™ 3B hydrodynamic acoustic recording tag attached with suction cups to a pantropical spotted dolphin (photo by Robin Baird, Cascadia Research, NMFS Scientific Research Permit No. 731-1774)***

## **OBJECTIVES**

As the developer of the Acousonde, Greeneridge Sciences' objectives in its collaboration with the University of New Hampshire are: (1) to guide improvement of TrackPlot for maximum compatibility with the Acousonde; (2) to refine the Acousonde's data calibration and storage of metadata to support TrackPlot most effectively; and (3) to revise the Acousonde hardware to remedy any shortcomings brought to light by TrackPlot applications using Acousonde data.

## **APPROACH**

The principal investigator will collaborate with Dr. Colin Ware of the University of New Hampshire to ensure that the Acousonde hardware and software provide all necessary data and metadata to maximize TrackPlot's accuracy and ease of use. The collaboration will also evaluate the precision and accuracy of the Acousonde's orientation and heading sensors, and document the methodology of acquiring and analyzing kinematic data from initial tagging to final interpretation.

To evaluate the Acousonde and TrackPlot under realistic conditions and to accelerate transition to the field-biology community, the investigators will test the tools with separately supported biology partners. They will train those partners in the use of the tools, adapt the tools to partners' needs, and assist with initial data interpretation. Investigators who have deployed the Acousonde in the field and are working with TrackPlot include the partnership of Mr. John Calambokidis and Dr. Jeremy Goldbogen of Cascadia Research with Dr. Erin Oleson of NOAA Fisheries and Dr. John Hildebrand of the Scripps Institution of Oceanography; and Dr. Kate Wynne and Ms. Bree Witteveen of the University of Alaska (Fairbanks).

With the Acousonde's behavioral sensors and software tested, the project will change focus to mechanical and attachment objectives specific to optimizing cetacean applications. The tag electronics will be reconfigured for casting in a unified suction-cup-and-electronics package together with a release mechanism, a housing for a VHF retrieval beacon, and sufficient buoyancy to assure flotation in the correct attitude for efficient VHF transmission.

## WORK COMPLETED

Since project inception on 18 June 2009 nearly all objectives have been accomplished. Specific milestones include the following: (1) the North-East-Down (NED) compass/accelerometer convention was chosen as the reference frame for the kinematic sensors in collaboration with Dr. Ware; (2) a completed Acousonde was delivered to the permanent custody of Dr. Ware for evaluation and continuing improvement of TrackPlot; (3) Dr. Ware supplied feedback on compass calibration that has now been incorporated into the Acousonde operating firmware; (4) the PI provided technical support to the Calambokidis et al. partnership for deployments of several Acousonde units on blue whales off of Los Angeles in 2010 and 2011, as well as to the Wynne/Witteveen partnership for deployments on humpback whales off Alaska in August 2011; (5) the Acousonde electronics were completely reconfigured to fit in a unified suction-cup-and-electronics package called the Acousonde 3B, announced in January 2011; (6) two Acousonde 3B units were constructed for the purpose of testing and evaluation; and (7) the PI joined Dr. Robin Baird of Cascadia Research and Dr. Oleson in field tests of the Acousonde off the Big Island of Hawaii in May 2011 (Figure 1).

## RESULTS

While technical surprises and delays hampered progress in FY10, FY11 saw abundant results, principally the completion and successful testing of the Acousonde 3B unified hydrodynamic tag. Unlike the cylindrical Acousonde 3A and its predecessor the Bioacoustic Probe that relied on third-party attachment and flotation, the 3B's industrial design incorporates flotation and attachment to provide the smallest and most hydrodynamic unified tag possible for these electronics.

The 3B's first field trial in May 2011 surpassed all expectations. Despite attachment to a smaller and more dynamic species than planned — a pantropical spotted dolphin — the tag remained attached for 12 hours 18 minutes, filling available acoustic storage and continuing kinematic sampling until shut down after retrieval.

The field test suggested the 3B's hydrodynamics to have advanced the tag's capabilities in two ways. First, lower drag likely lengthened attachment duration; it not only put less immediate stress on the attachment but also delayed the tag's rearward migration towards the flukes, where vigorous movement would have accelerated the tag's release. Second, lower drag quieted flow noise, improving low-frequency signal-to-noise and supporting recording of weaker signals.

While field tests of the 3B were being planned, contacts with the Vancouver Aquarium began in hopes of conducting joint captive studies with beluga whales. A mechanical sample of the 3B was sent to Mr. Brian Sheehan of the Aquarium in April 2011, who offered many helpful suggestions for improvement; but by June it became clear that the skin of their captive beluga would not easily support attachment of the 3B as designed. Mr. Sheehan recommended a pair of large, widely spaced suction cups to replace the 3B's cluster of four smaller cups, but redevelopment was not feasible at the time and the effort was shelved.

Two separate partnerships successfully deployed the Acousonde electronics on cetaceans in FY11 that subsequently worked with TrackPlot to analyze kinematic behavior. Mr. Calambokidis and his partners deployed Acousonde 3B packages on blue whales off of Los Angeles, obtaining data from one

instance of a ship's near approach. The reduced drag of the 3B allowed this project to use a more sensitive hydrophone that recorded ship noise clearly while still not overloading from flow noise. Support for this effort came from ONR as well as from NOAA's Channel Islands National Marine Sanctuary. Meanwhile, Dr. Wynne and Ms. Witteveen attached an Acousonde 3A to a humpback whale off Alaska as part of an acoustic deterrent study (Figure 2), supported by the NOAA Gulf Apex Predator-prey program. These investigators succeeded without on-site support from the PI, confirming the Acousonde design's suitability for transition outside the program.



***Figure 2. Photograph of an Acousonde™ 3A acoustic recording tag attached with suction cups to a humpback whale (photo by Bree Witteveen, University of Alaska (Fairbanks), NMFS Scientific Research Permit No. 14296)***

## **IMPACT/APPLICATIONS**

Acoustic recording tags measure sounds that a tagged animal makes or to which it is exposed, and monitor potentially associated changes in the animal's behavior. This quantitative knowledge of stimulus and response is fundamental to our understanding of protected species' acoustic sensitivity. For calling animals, the tags' acoustic data can clarify the statistics of individual vocalization, while behavioral data from the depth and kinematic sensors help place a subject's calling activity in context. These advances from acoustic recording tags may in turn provide a better interpretive foundation for studies that rely on fixed acoustic monitors.

While prior work focused on improving the acoustic capabilities of the Acousonde, the present effort concentrates on the acquisition and interpretation of behavioral kinematic data and its comparison with the acoustics. The effort will provide the wider bioacoustic research community with access to high-quality kinematic visualization of the behavior of tagged subjects. This visualization capability will support the creation and testing of scientific hypotheses in ways that raw kinematic time series cannot.

The Acousonde is finding increasing utility in non-biological applications. As detailed below under transitions, such applications include vessel signatures, minesweeper testing, tactical oceanography, underwater gliders, and marine geophysics. Improvements to kinematic sensing and analysis under the present effort may increase the recorders' utility in these fields as well.

## **TRANSITIONS**

The Acousonde and its predecessor, the Bioacoustic Probe, have been widely applied in acoustic research. Thirty-eight Acousondes and 43 Bioacoustic Probes have been built; 22 different research groups have applied them. Under Dr. John Hildebrand of the Scripps Institution of Oceanography and Mr. John Calambokidis of Cascadia Research, the instruments have been attached to blue whales (Oleson et al., 2007), fin whales (Goldbogen et al., 2006), and humpback whales; under Calambokidis and Dr. Aaron Thode of Scripps and, independently, Dr. Bruce Mate of Oregon State University, to sperm whales; under Dr. Whitlow Au of the Hawaii Institute of Marine Biology (HIMB), and, independently, Dr. Kate Wynne and Ms. Bree Witteveen of the University of Alaska (Fairbanks), to humpback whales; under Dr. Stephen Insley, then at the University of California at Santa Cruz, to northern fur seals (Figure 3; Insley et al., 2007); and under Dr. Chip Deutsch of the Florida Fish and Wildlife Research Institute to manatees. Dr. Carl Meyer of HIMB temporarily sutured one B-Probe into a blacktip reef shark (Meyer et al., 2007). Most of these investigators will benefit from the improved kinematic analysis tools being introduced under the current program.

The instruments are finding applications beyond attachment to wildlife. Dr. Thode used Bioacoustic Probes as independent elements comprising a portable acoustic array (Thode et al., 2006) and as convenient self-contained tilt-meters for conventional acoustic arrays; Thode and Dr. Gerald D'Spain of Scripps used them as acoustic and attitude sensors during prototype trials of the Liberdade X-Ray underwater glider (D'Spain et al., 2005); and Dr. Jim Miller of the University of Rhode Island obtained one for use inside an autonomous underwater vehicle. Bioacoustic Probes and Acousondes have been employed as simple seafloor recorders in several studies, including a behavioral study of beluga-whale habitat usage (Burgess et al., 2005); geoacoustic studies of sediment properties by the University of Washington (Tang, 2005) and the Monterey Bay Aquarium Research Institute (Henthorn et al., 2009); and geophysical studies of bubble seeps (Leifer and Tang, 2006) and geothermal vents (Chadwick et al., 2008).

More recently, the PI collaborated with a shipbuilding contractor for the operational Navy to customize the Acousonde for noise assessment. This transition directly benefits fleet modernization. Meanwhile, the Naval Postgraduate School has used the Acousonde since 2009 for officer training in tactical oceanography, while in 2010 an Acousonde served as a fixed recorder in the Beaufort Sea on behalf of BP for studies of acoustic emissions from an offshore drilling island.



In August 2011, we collaborated in field work with Mr. Christopher Garner of Joint Base Elmendorf-Richardson (Anchorage, Alaska) and Dr. Manuel Castellote of the National Marine Mammal Laboratory to assess applicability of the Acousonde 3B to wild beluga in Cook Inlet, Alaska. No lasting attachment was achieved with any tag during this effort, but the possibility of transition for wild beluga work remains open.

As of this writing, NSWC Carderock is evaluating an Acousonde 3A for use on a trial basis to provide supporting data during hydrodynamic and acoustic characterization of an MK104 acoustic source. Testing is funded by the Unmanned Influence Sweep System (UISS) program under the PMS406 program office.



***Figure 3. Photograph of a northern fur seal at the Pribilof Islands, Alaska, fitted with the previous generation of the Acousonde (the Bioacoustic Probe). Also fitted to the subject are a satellite location transmitter and a VHF retrieval beacon (photo by Stephen Insley; Insley et al., 2007).***

## **RELATED PROJECTS**

The present work is a collaborative effort with Dr. Colin Ware of the University of New Hampshire, the creator of TrackPlot, separately supported under ONR Award number N00014-09-1-0601.

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